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(54) Polarimetric optical frequency domain distributed strain sensor and method.

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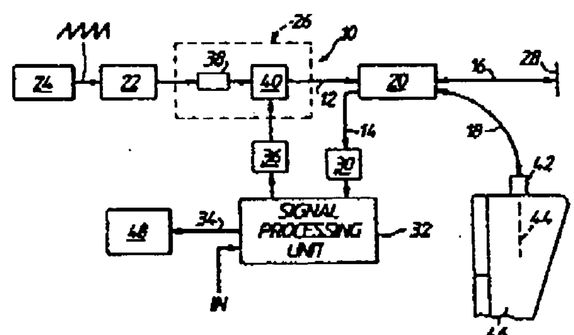

FIG.1.

EP 0 320 255 A3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 88 31 1618

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 4)
D,A	ELECTRONICS LETTERS, vol. 21, no. 10, 9th May 1985, pages 434-435; S. KINGSLEY et al.: "OFDR diagnostics for fibre and integrated-optic systems" ---		G 01 L 1/24
A	PROCEEDINGS OF SPIE - THE INTERNATIONAL SOCIETY FOR OPTICAL ENGINEERING, FIBER OPTIC AND LASER SENSORS III, San Diego, California, 20th - 23rd August 1985, vol. 566, pages 265-275; S.A. KINGSLEY et al.: "OFDR diagnostics for fiber/integrated optic systems and high resolution distributed fiber optic sensing" -----		
			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
			G 01 L G 01 M

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	20-10-1989	ZAFIROPOULOS N.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
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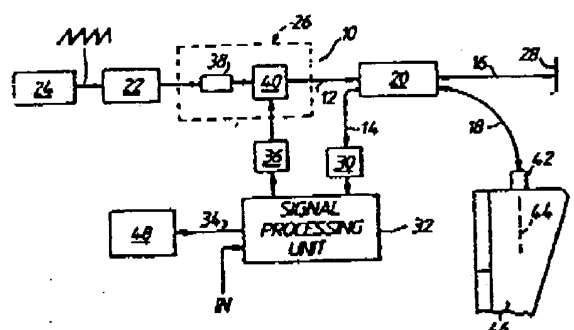


FIG.1.

EP 0 320 255 A2

POLARIMETRIC OPTICAL FREQUENCY DOMAIN DISTRIBUTED STRAIN SENSOR AND METHOD

The present invention relates to strain detection and, more particularly, to the detection of strain distributed along an optical fibre.

Various apparatus and systems have been developed for distributed strain or stress detection. In the electrical domain, for example, the effects of strain on a transmission line can be detected by time-domain reflectometry techniques in which an electrical interrogation pulse of known characteristics is transmitted on a transmission line. Any strain-induced faults in the line will alter the characteristic impedence of the line to some extent and reflect part of the interrogation pulse to its source. The distance between the interrogation signal source and the strain point can be determined from the round trip time for the transmission of the interrogation pulse and the reception of the reflected pulse and from the propagation velocity within the line. In an analogous manner, the strain-induced faults or discontinuities in an optical fibre can be determined by launching a defined optical interrogation pulse into a fibre which is subjected to strain and measuring the elapsed time from the launching of the interrogation pulse to the reception of the reflected pulse.

The measurement of the strain on an elongated energy transmitting line has application in composite structures as used in aircraft and spacecraft. Composite materials, such as graphite/epoxy laminates, provide significant increases in strength-to-weight performance compared to traditional metal structures, principally aluminium alloy, used in airframes. In applications where the structure is subjected to recurring time-varying stress as typically encountered in an aircraft application, the composite tends to fail catastrophically in an unpredictable manner and without advanced warning. Metal structures, in contrast, tend to fail by first developing micro-cracks which propagate with continued stress in a reasonably predictable manner until a total failure occurs. Various techniques, including Magna-flux type detection systems, are available for reliably detecting micro-cracks in metal structures prior to their failure. Composite structures, on the other hand, are not well-suited for existing micro-crack detection techniques and, accordingly, a problem is presented in the non-destructive detection of prefailure indicia.

Discrete strain gauges are typically used to sense strain at a defined location and can be attached to a composite structure. However, discrete location sensing may not provide meaningful information for a large composite structure and the need for wiring between the sensors and a central controller creates a practical upper limit for the number of strain sensors that can be employed. Additionally, a large number of discrete sensors attached to a composite structure can represent a significant cost disadvantage as well as compromising the design flexibility of the system.

While the sensing of the structural integrity of a composite structure has principal utility in airframe evaluation, the sensing of the structural integrity is also useful in the military environment in which the structure may be subjected to ballistic impact. A sensing system for a composite structure would ideally be able to function as an intelligent structure and provide an automatic and reliable assessment of structural integrity immediately after a ballistic impact.

One type of sensing system which has been suggested as suitable for structural integrity sensing of composite structures has been presented by Kingsley, S. and Davies, D. in Electronic LettersOFDR Diagnostics for Fibre and Integrated-Optic Systems, May 9, 1985, Vol. 21, No. 10, Pg. 434-5. The Kingsley system relies on the frequency-altering effects of strain on an optical interrogation pulse in contrast to the time-domain effects described above. The system includes a laser diode which is driven by a time-varying current pulse to produce a frequency varying optical chirp launched into an optical fibre. As the frequency varying interrogation pulse propagates along the optical fibre, selected frequency components of the interrogated light are subject to back-scatter toward the source with the back-scatter at any point in the line being a function of the attendant strain at that point. The amplitude of the return signals is a function of the back-scatter at the strain location as well as the cumulative effect of impurities, inclusions, micro-bending, and other attenuation producing factors. The light back-scattered from the fibre is optically mixed with a reference signal from the source laser, and beat frequencies are produced with the beat frequency related to the position of the associated strain along the fibre. The Kingsley system represents a device which determines the optical loss along an optical waveguide and functions as a passive, open loop distributed intensity sensing device. Since the returned optical signal includes both an information signal and the equivalent of background noise caused by the cumulative effect of core imperfections, the signal-to-noise ratio of the Kingsley system diminishes with increased sensing fibre length and, accordingly, suffers from an inability either to zero-null the system or to increase the sensitivity of the system for a selected portion of the sensing

fibre.

According to the invention, there is provided a method of sensing strain in an optical fibre, comprising the steps of launching frequency-varying optical energy into the optical fibre, producing a reference signal representative of the optical energy, and mixing a portion of the optical energy back-scattered from the fibre with a portion of the reference signal to produce a beat signal, characterised by the steps of sensing the polarization state of the optical energy back-scattered in the fibre, and controlling the polarization state of the launched optical energy in response to the sensed polarization state.

According to the invention, there is also provided a system for sensing strain in an optical fibre and for carrying out the foregoing method, comprising source means for launching frequency-varying optical energy into the optical fibre, reference means for providing a reference signal representative of the optical energy, and mixing means for mixing optical energy back-scattered from the fibre with the reference signal to produce a beat signal, characterised by polarization means for selectively controlling the polarization state of the launched optical energy, sensing means for sensing the polarization state of the back-scattered optical energy, and control means for adjusting the polarization means in dependence on the sensed polarization state.

Optical frequency domain distributed strain sensor systems embodying the invention will now be described, by way of example only, with reference to accompanying drawings, in which like parts are designated by like reference characters:-

FIGURE 1 is a schematic block diagram of one of the optical frequency domain distributed strain sensor systems for detecting strain distributed along a sensing optical fibre embedded within a composite structure;

FIGURE 2 is an idealized graphical representation of an amplitude vs. frequency plot illustrating beat frequency output;

FIGURE 3 is a functional block diagram of a signal processing control unit illustrated in FIGURE 1;

FIGURE 4 is a flow diagram of a control sequence for incrementally interrogating sucessive sections of the optical fibre sensor;

FIGURE 5 is a schematic diagram of a variation of the optical frequency domain distributed strain sensor of FIGURE 1;

FIGURE 6 is a schematic diagram of another of the optical frequency domain distributed strain sensor systems;

FIGURE 7 is a schematic diagram of a further one of the optical frequency domain distributed strain sensor systems; and

FIGURE 8 is a schematic diagram of yet another one of the optical frequency domain distributed strain sensor systems.

As will be described in more detail below, the systems provide closed loop optical frequency domain distributed strain sensors for determining the strain distribution along a sensing optical fibre. A polarized optical signal having a frequency which varies in a recurring, preferably linear, manner is injected into the sensing optical fibre. The portion of the interrogation signal back-scattered from the sensing fibre is mixed with a reference signal to produce beat frequency signals. The frequency of the beat signals is directly related to the position of back-scatter in the sensing fibre while the amplitude of each beat frequency signal is directly related to the integrated strain-induced birefringence up to the back-scatter point. An in-line fibre polarizer and an associated polarization controller control the tion state of the interrogation signal to provide zero point sensitivity compensation and controllable testing for ambiguous strain points.

The optical frequency domain distributed strain sensor system in FIGURE 1 is designated generally therein by the reference character 10. As shown, the sensor system 10 comprises a single-mode optical fibre circuit which includes an input fibre 12, an output fibre 14, a reference fibre circuit 16, and a sensor fibre circuit 18 described more fully below. The various fibres are interconnected through an optical coupler 20 so that optical energy from the input fibre 12 is distributed to the reference fibre circuit 16 and the sensor fibre circuit 18 and optical energy from both the reference fibre circuit 16 and the sensor fibre circuit 18 is distributed to the output fibre 14. The coupler 20 may take the form of a discrete device, an integrated-optic device, or a simple lateral coupling between the fibres. Where a lateral coupling is utilized, the input fibre 12 and the reference fibre circuit 16 can be formed from a single fibre and, in an analogous manner, the output fibre 14 and the sensor fibre circuit 18 can be formed from a single fibre with both fibres laterally coupled over a discrete length to effect the desired optical coupling.

An optical source 22 is driven by a variable current source 24 as described below to introduce recurring optical interrogation pulses which are passed through a polarization controller, indicated generally at 26, to the coupling 20 for distribution to the reference fibre circuit 16 and the sensor fibre circuit 18. The remote end of the reference fibre circuit 16 is provided with a reflective end surface 28 which is effective to reflect optical energy back towards the coupling 20 for distribution into the output fibre 14 to a photodetector 30 connected in circuit with a signal processing unit 32. Output

information as to the sensed strain and its distribution is provided on information output 34 with control signals provided to a driver 36 which, in turn, provides control signals to the polarization controller 26. The polarization controller 26 includes a polarizer 38 which functions to polarize the optical energy from the optical source 22 in an arbitrary initial state and a selectively controllable polarizer 40 which rotates or otherwise alters the polarization state of the optical energy provided through the polarizer 38 in response to control signals provided by the polarization driver 36 The controllable polarizer 40 permits an arbitrary amount of bias retardation to be introduced into the optical interrogation signal passed through the coupler into the sensor fibre circuit 18. The controllable polarizer 40 can take the form of an electrically controlled PZT material, for example, through which the optical energy is passed.

A connector 42 is provided in the sensing fibre circuit 18 and connects to a sensing fibre 44 which is embedded or otherwise attached to a strain-producing structure 46, such as a graphite/epoxy composite which is subject to strain. In the embodiment of FIGURE 1, the strain-producing structure 46 is presented as a portion of the wing structure of an aircraft.

In a preferred embodiment, the optical source 22 takes the form of a laser diode which produces a variable frequency output as a function of its drive current. The variable current source 24 provides a current output which includes a constant current bias with a superimposed recurring ramp (i.e., a sawtooth pattern) to cause the optical source 22 to provide a recurring optical signal output which varies in frequency in a time-predictable, preferably linear, manner from an initial frequency F1 to a second frequency F2. A representative optical source 22 includes the Hitachi HLP1600 laser diode which produces an output in the 850 nm. range and can be driven by currents in the 100 ma. range to produce frequency deviations between frequencies F1 and F2 of the order of 100 GHz or so. In this preferred embodiment, the optical energy from the laser diode is polarized along a selected or otherwise predetermined orientation and the polarizer 38 is aligned with the initial polarization of the laser diode for maximum transmission to the controllable polarizer 40.

The optical interrogation pulses provided by the optical source 22 are launched into controllable polarizer 26 with the polarization state initialized by the polarizer 38 and this initial polarization state is further altered by the variable polarizer 40 to provide interrogation pulses of an initially predetermined orientation along the input fibre to the coupler 20. A portion of the interrogation signal enters the reference fibre circuit 16 and a portion of the interrogation signal also enters the sensor fibre circuit 18. The portion of the interrogation signal entering the reference fibre circuit 16 is reflected at 28 and a portion of that reflected energy is passed through the coupler 20 into the output fibre 14 and to the photodetector 30. A portion of the optical interrogation pulse provided through the coupler 20 from the optical source 22 is passed into the sensor fibre circuit 18 and through the connector interface 42 and to the sensing fibre 44. Any stress or strain to which the composite structure 46 is subjected will be presented to the sensor fibre 42.

As is known, optical energy transmitted through an optical fibre core will be subjected to back-scattering because of the presence of impurities in the core or at the core/cladding interface, particulate inclusions, and variations in the density of the core silica or a variation in the concentration of the dopants. In addition, back-scattering is a function of the relative stress that the core is subjected to, this stress causing relative changes in the index of refraction which represent a change in transmission impedance sufficient to increase or decrease back-scatter.

As a consequence of the strain experienced along the length of the sensor fibre 44 within the composite structure 46, portions of the polarized interrogation pulse will be back-scattered toward the source with back-scatter increased at various points along the sensing fibre 44 as a function of any strain sufficient to increase back-scatter.

The polarization state of the interrogation energy will be modified as a function of the stress presented to the fibre core by the structure 46 acting on the sensing fibre 44.

The back-scattered optical energy is returned through the connector 42 and the fibre 18 to the coupler 20. The reference signal returned through the reference signal circuit 16 to the coupler 20 is optically mixed with the back-scattered optical energy provided from the sensor fibre circuit 18. The two signals, that is, the reference signal provided through the reference signal circuit 16 and the back-scattered information-bearing signal from the sensing fibre 44 are effectively autodyned to produce sum and difference beat frequency signals of which the difference signals represent strain-magnitude and location information. The beat signals are presented to and detected by the photodetector 30 which provides an electrical output to the signal processing unit 32.

As shown in idealized fashion in FIGURE 2, the frequency of the back-scattered information signal is a direct function of the distance to the back-scatter point or location in the sensing fibre 42 where the strain-induced back-scatter originates; a lower frequency beat signal represents back-scatter locations which are closer to the source than rela-

tively higher frequency beat signals. The relationship between the various beat signals and their amplitudes can be analyzed, for example with a spectrum analyzer 48, to provide scale factor information for the frequency-spaced beat signals. The amplitudes of the various beat signals are directly related to the integral of the strain-induced birefringence along the fibre up to the point at which the back-scatter originates: a lower strain produces a lower back-scatter and a lower amplitude beat frequency signal when optically mixed with the reference signal.

Since the amount of back-scattered light increases wth increased sensing fibre lengths, the ability to discriminate strain-induced birefringence at a selected location relative to background noise, can be diminished in certain applications. Thus, as the polarized interrogation light travels down the sensing fibre 44, its polarization state will be affected by the distributed birefringence along the fibre core. Likewise, light back-scattered from a strain location of interest will be subjected to additional changes in its polarization state. As can be appreciated, the polarization controller 26 allows a high degree of control of the polarization of the interrogation energy in such a way that the cumulative or integrated effects of strain-induced birefringence on the polarized interrogation light can be nulled from the output so that selected path lengths of the sensing fibre 44 can be effectively tuned, for greater sensitivity. More specifically, the polarization controller 26 can be adjusted to reorient the polarization state of the optical interrogation pulse to null out the effect of strain-induced birefringence for a selected portion of the sensing fibre 44 so that back-scatter from a location downstream of a selected location will not be affected by the cumulative strain-induced back-scatter up to that location. Additionally, the polarization controller 26 can be used to zero-null the system. When the composite structure 46 is in an unstressed state, the polarization controller 26 is adjusted by an appropriate signal from the polarization driver 36 to compensate for and null out the quiescent, cumulative birefringence in the sensing fibre 44 so that a higher signal-to-noise ratio will be obtained when the composite structure 46 is subjected to strain.

In addition, the system can interrogate a specific location in the sensing fibre 44, or more preferably, interrogate successive locations to obtain distributed strain information. More specifically and as shown in the functional block diagram of FIGURE 3 and the flow diagram of FIGURE 4, the signal processing unit 32 of FIGURE 1 includes a controllable frequency filter 50 which receives the returned signals and, after filtering, feeds the filtered signals to a polarization state analyzer 52. The frequency filter 50, which can take the form of an active filter, is selectively controllable to establish a cut-off frequency Fco and effectively functions as a low-pass filter below that cut-off frequency. Since the frequency of the returned signals is a function of the distance along the sensing fibre 44 of any strain-induced birefringence location, a selected cut-off frequency Fco will effectively pass light returned along the sensing fibre 44 up to that selected location and attenuate light beyond the selected location. The polarization state analyzer 52 operates to sense a polarization state, e.g., one or more of the Stokes parameters, and provides an output indication to a control processor 54 which, in response to an input signal issues appropriate commands to the polarization driver 36. The feedback path provided through the polarizer driver 36 thus serves to provide a closed, active control loop in which the polarization controller 26 is operated in response to the output of the processor 54. The processor 54 is of conventional organization and includes I/O and data ports, a read-only memory (ROM) containing a stored control program which implements the sequence described below and shown in FIGURE 4, a random-access memory (RAM) for storing values assigned to variables, an arithmetic-logic unit (ALU), one or more storage registers Reg. A, Reg. B, Reg. C ...., for manipulating data, and a clock CLK.

An exemplary control program for interrogating N selected locations along the sensing fibre 44 wih a closed-loop autonull is shown in the flow diagram of FIGURE 4. As shown, a variable N is initialized to 1 and the processor 54 commands the frequency filter 50, to operate at a cut-off frequency Fco(N-) to pass return signals for a location N-, the N- location being just prior to the location N of interest. Thereafter, the processor 54 controls the polarization driver 36 to change the polarization parameters until a selected polarization state is detected by the polarization state analyzer 52 with the frequency range passed by the frequency filter 50, this signal detection indicating that an interrogation signal of a known polarization state is being provided to the location N-. Thereafter, the processor 54 controls the frequency filter 50 to change (viz., increase) the cut-off frequency Fco(N) to a frequency for the location N of interest. The polarization state of the returned signals of the location N is compared with the immediately preceding location N- with the changes being a function, in part, of the strain-induced birefringence at the location N of interest. The variable N is incremented and the procedure continued in a recurring sequence until the variation N attains its preselected maximum.

As can be appreciated by those skilled in the art, the frequency filter 50 can be operated in a manner converse to that described above, that is,

an initial, relatively high Fco can be selected and subsequently lowered in decremental steps in contrast to the incrementing described above. In addition, the frequency filter 50 can be controlled to provide a pass band function which allows a relatively higher gain interrogation of a selected segment of the sensing fibre 44.

A variation of the optical frequency domain distributed strain sensor of FIGURE 1 is shown in FIGURE 5 and designated generally therein by the reference character 10, and in which like reference characters refer to like components. As shown, the polarization controller 28 is relocated to the sensor fibre circuit 18 under the control of the polarization driver 36 and the signal processing unit 32 to control the interrogation signal in a manner consistent with that of the embodiment of FIGURE 1 and the control program of FIGURE 4.

In the embodiments of FIGURES 1 and 5, the optical interrogation signals and their returned signals are optically mixed to obtain distributed strain information for the sensing fibre 44. In addition to optical mixing, electrical domain mixing can be used to obtain the desired information. In this case, the optical signal itself is not chirped, but is modulated via a linear FM ramp modulation of the laser diode. As shown in FIGURE 6, the output of the photodetector 30 is provided along path 56 to an RF mixer 58 which accepts the functional equivalent of a local oscillator signal along path 60 from the driver 24. The output of the RF mixer 58 is fed along path 62 to the signal processing unit 32 for processing in a manner consistent with that discussed above.

A variation of the embodiments of FIGURES 5 and 6 is shown in FIGURE 7 in which the signals returned along the fibre 14 are presented to a polarization state analyzer 52 which provides each of the Stokes vector parameters to the mixer 58 via path 56 in a successive serial manner (e.g., time-division multiplexing).

In the various embodiments described above, the optical source 22 is modulated by a time-varying drive current. In the embodiment of FIGURE 8, the optical source 22 is driven by a constant current source 24, to provide a continuous wave (CW) output to the polarization controller 26, the coupler 20, and the reference signal circuit 16. A portion of the continuous wave energy is fed through the coupler 20 to the sensor fibre circuit 18 for intensity modulation by an optical intensity modulator 64 which is driven by an RF driver 66 which is effective to modulate the intensity of the continuous wave interrogation between two values in a recurring manner. The optical intensity modulator 64 may take the form of a light transmitting material which is responsive to the electrical stimulation of the RF driver 66 to affect light transmission through the material. The intensity modulated interrogation energy enters the sensing fibre 44 and is back-scattered and time-delayed from the instantaneous intensity modulation imposed by the modulator 64 with beat signals produced which correspond with the origination location of the back-scattered signals. The beat signals are fed to the polarization state analyzer 52 and to the signal processing unit 32 to provide location and strain distribution information.

The embodiments described thus advantageously provide polarimetric optical frequency domain distributed strain sensor systems which include controllable polarization optics and retardation optics which can actively modify the polarization state of the modulated interrogation energy injected into the sensing fibre. The polarization controller can be used to "null out" the birefringence effects of any portion of the sensing fibre to allow selected points to be interrogated at a maximum signal-to-noise ratio. Alternatively, the returned optical signal can be maintained at some quadrature condition just before a measurement point and the stress at that point determined from the control input to the controllable polarizer.

It will be apparent and is contemplated that modification and/or changes may be made in the illustrated embodiments without departure from the invention. Accordingly, it is expressly intended that the foregoing description and accompanying drawings are illustrative of preferred embodiments only and not limiting, and that the true spirit and scope of the present invention will be determined by reference to the appended claims and their legal equivalent.

Claims

1. A method of sensing strain in an optical fibre (44), comprising the steps of launching frequency-varying optical energy into the optical fibre (44), producing a reference signal representative of the optical energy, and mixing a portion of the optical energy back-scattered from the fibre (44) with a portion of the reference signal to produce a beat signal, characterised by the steps of sensing the polarization state of the optical energy back-scattered in the fibre, and controlling the polarization state of the launched optical energy in response to the sensed polarization state.

2. A method according to claim 1, characterised in that the controlling step comprises the step of so controlling the polarization state of the launched optical energy in response to the sensed polarization state in the absence of strain applied to the optical fibre (44) as substantially to null quiescent cumulative birefringence in the fibre (44).

3. A method according to claim 1, characterised in that the controlling step comprises the step of so controlling the polarization state of the launched optical energy in response to the polarization state sensed at a frequency of the beat signal corresponding to a particular location along the fibre (44) and which is subjected to strain that the effect of back-scatter at locations other than the predetermined location is reduced.

4. A method according to claim 1, characterised in that the sensing step comprises the step of sensing the polarization state of the back-scattered optical energy from the fibre (44) at frequencies in the beat signal lying on one side of a datum frequency which corresponds to a selected location in the fibre (44) adjacent to a particular location therein which is subjected to strain, in that the controlling step comprises the step of controlling the polarization state of the launched optical energy in response to the sensed polarization state whereby to minimise back-scatter, and by the step of changing the value of the datum frequency so that it corresponds to the particular location whereby the beat signal is representative of strain at the particular location.

5. A method according to claim 4, characterised in that the sensing step is repeated for a different datum frequency and which corresponds to a location adjacent to a second predetermined particular location in the fibre (44) which is subjected to strain, in that the controlling step is repeated in response to the polarization state sensed in the repeated sensing step, and by the step of changing the different datum frequency to correspond to the second particular location whereby to produce a second beat signal representative of strain at the second particular location.

6. A method according to any preceding claim, characterised by the step of attaching the fibre to a structure or object (46) so as to be subjected to the strain thereof.

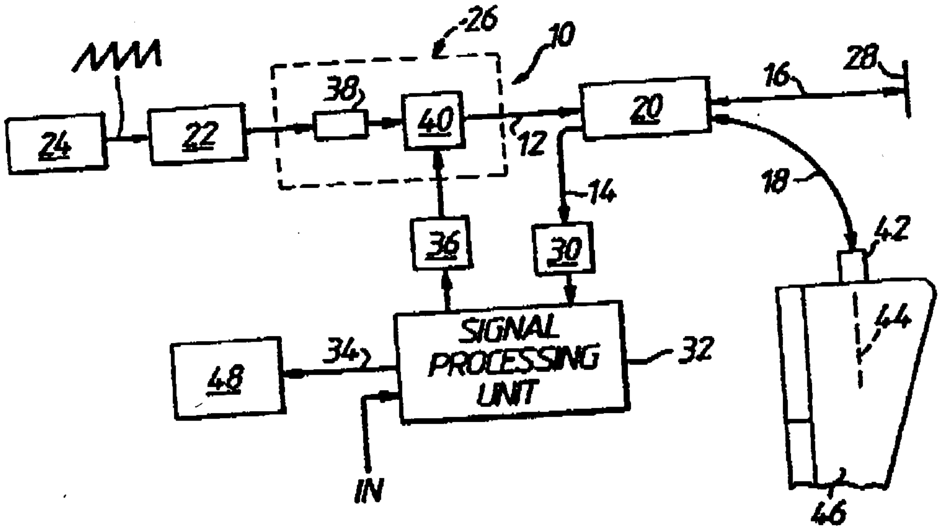
7. A system for sensing strain in an optical fibre (44) and for carrying out a method according to any preceding claim, comprising source means (24; 24, 64) for launching frequency-varying optical energy into the optical fibre (44), reference means (16, 28) for providing a reference signal representative of the optical energy, and mixing means (20) for mixing optical energy back-scattered from the fibre (44) with the reference signal to produce a beat signal, characterised by polarization means (26) for selectively controlling the polarization state of the launched optical energy, sensing means (32; 52) for sensing the polarization state of the back-scattered optical energy, and control means (36) for adjusting the polarization means (26) in dependence on the sensed polarization state.

8. A system according to claim 7, characterised in that the control means (36) comprises means for adjusting the polarization means (26) in dependence on the sensed polarization state in the absence of strain applied to the optical fibre (44) whereby substantially to null quiescent cumulative birefringence in the fibre (44).

9. A system according to claim 7, characterised in that the sensing means comprises means (32) for sensing the polarization state of the optical energy at a frequency of the beat signal corresponding to a particular location along the fibre (44) which is subjected to strain, and in that the control means (36) so controls the polarization state of the launched optical energy as to reduce the effect of back-scatter at locations other than the said particular location.

10. A system according to claim 7, characterised in that the sensing means (32; 52) comprises means for sensing the polarization state of the back-scattered optical energy from the fibre (44) at frequencies in the beat signal lying on one side of a datum frequency which corresponds to a selected location in the fibre (44) adjacent to a particular location therein which is subjected to strain, in that the control means comprises means (36) for adjusting the polarization means (26) in response to the sensed polarization state whereby to minimise back-scatter and by means (32) for changing the value of the datum frequency so that it corresponds to the particular location whereby the beat signal is representative of strain at the particular location.

11. A system according to any one of claims 7 to 10, characterised in that the optical fibre (44) is attached to a structure or object (44) so as to by subjected to the strain thereof.


26
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SIGNAL PROCESSING UNIT
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FIG.1.


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FIG.2.

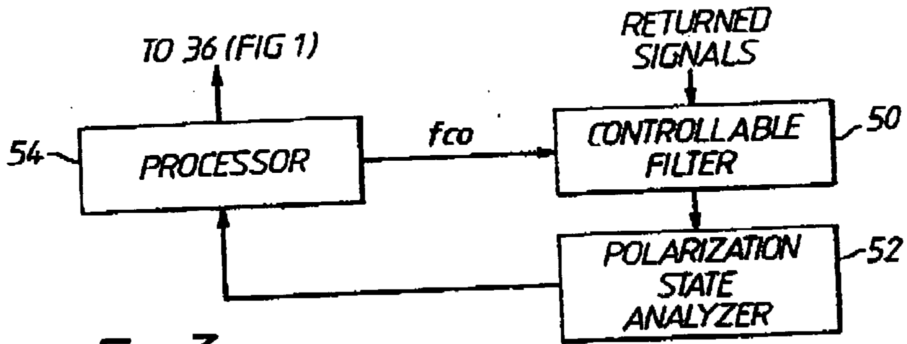
TO 36 (FIG 1)
RETURNED SIGNALS
54
PROCESSOR
fco
CONTROLLABLE FILTER
50
POLARIZATION STATE ANALYZER
52

FIG. 3.

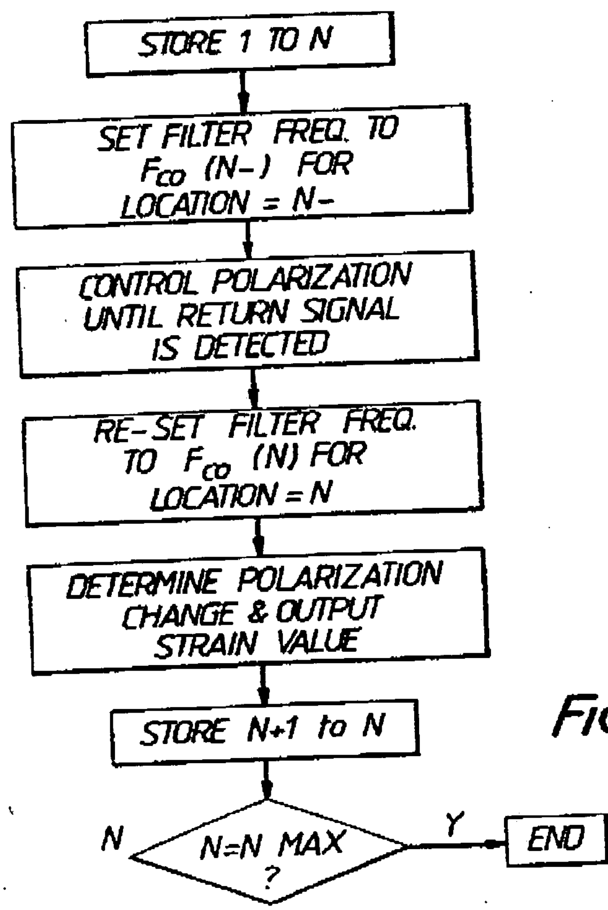
STORE 1 TO N
SET FILTER FREQ. TO F_{co} (N-) FOR LOCATION = N-
CONTROL POLARIZATION UNTIL RETURN SIGNAL IS DETECTED
RE-SET FILTER FREQ. TO F_{co} (N) FOR LOCATION = N
DETERMINE POLARIZATION CHANGE & OUTPUT STRAIN VALUE
STORE N+1 to N
N
N=N MAX ?
Y
END

FIG. 4.

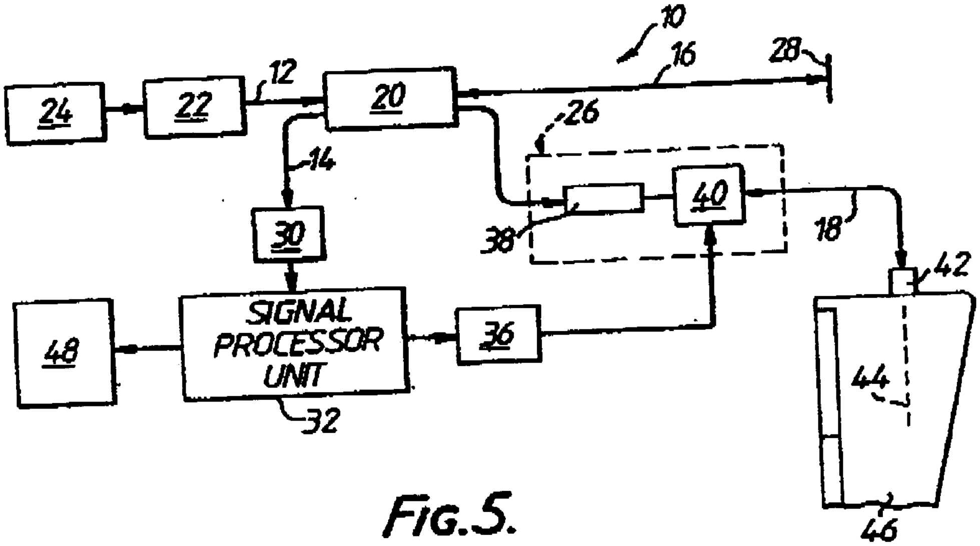
10
16
28
12
24
22
20
26
14
40
38
18
30
42
SIGNAL PROCESSOR UNIT
48
36
44
32
46

FIG.5.

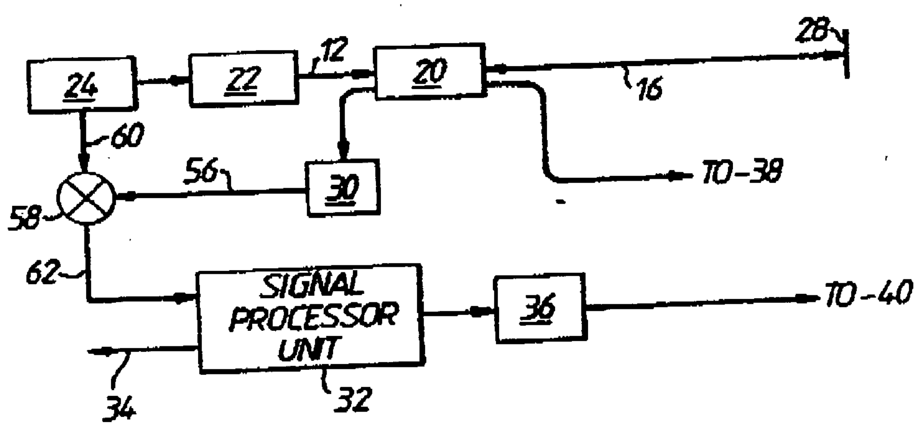
28
12
24
22
20
16
60
56
30
TO-38
58
62
SIGNAL PROCESSOR UNIT
36
TO-40
34
32

FIG.6.

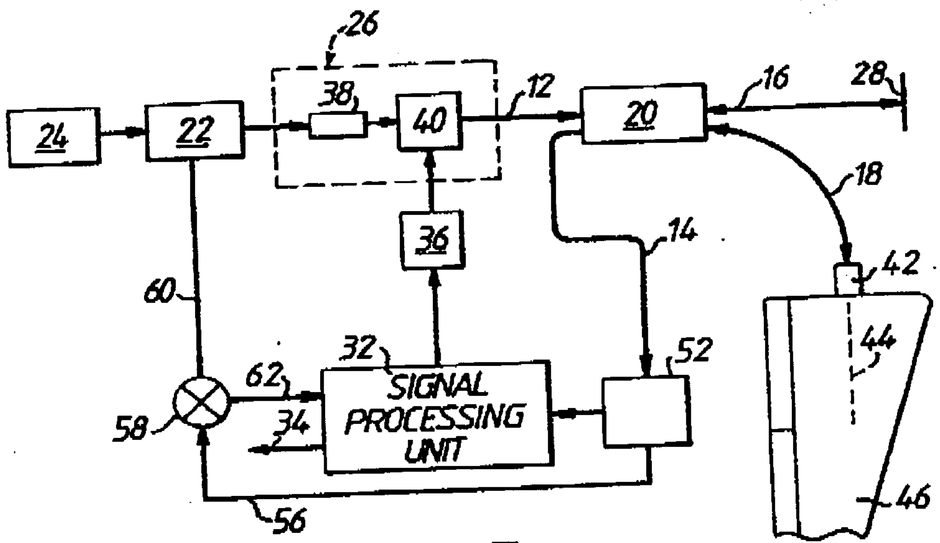
26
38
40
12
20
16
28
24
22
18
36
14
42
60
32
52
44
62
SIGNAL PROCESSING UNIT
58
34
46
56

FIG.7.

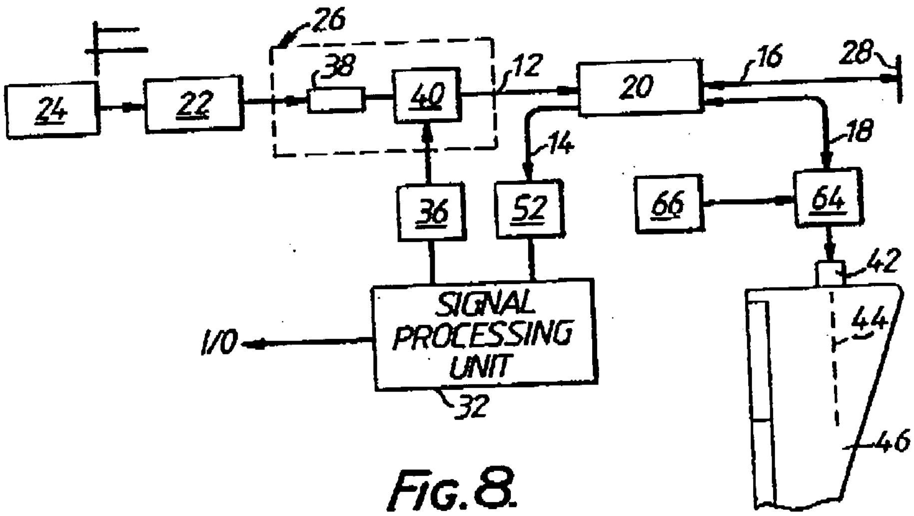
26
38
40
12
20
16
28
24
22
18
14
36
52
66
64
42
44
SIGNAL PROCESSING UNIT
I/0
32
46

FIG.8.